

Claims

- [c1] 1. A voltage-controlled oscillator (VCO) comprising:
- an output clock having an output frequency;
 - an input having an input voltage that is varied to vary output frequency;
 - a variable current source, responsive to the input, for varying a current to a source node in response to the input voltage;
 - a ring oscillator that generates the output clock, the ring oscillator having the source node supplying current to transistors in the ring oscillator wherein varying a source voltage of the source node varies the output frequency of the output clock generated by the ring oscillator;
 - a bypass capacitor coupled to the source node; and
 - an active resistor coupled in parallel with the ring oscillator to the source node, the active resistor having a series resistor and a series transistor in series,
 - whereby the active resistor in parallel with the ring oscillator lowers an R-C time constant of the source node.
- [c2] 2. The voltage-controlled oscillator of claim 1 wherein the series transistor has a gate driven by a constant bias voltage.

- [c3] 3.The voltage-controlled oscillator of claim 2 wherein the ring oscillator comprises a plurality of inverting stages, each inverting stage having a p-channel pull-up and an n-channel pull-down transistor having drains driving an input to a next stage in the plurality of inverting stages.
- [c4] 4.The voltage-controlled oscillator of claim 3 wherein the plurality of inverting stages comprises exactly 3 stages in a loop.
- [c5] 5.The voltage-controlled oscillator of claim 3 wherein the source node is connected to sources of p-channel pull-up transistors in the plurality of inverting stages.
- [c6] 6.The voltage-controlled oscillator of claim 5 wherein the active resistor is connected between the source node and a ground.
- [c7] 7.The voltage-controlled oscillator of claim 6 wherein the series transistor is an n-channel transistor.
- [c8] 8.The voltage-controlled oscillator of claim 7 wherein the variable current source is coupled between a power supply and the source node; wherein the source node is a virtual power-supply node to the ring oscillator.

- [c9] 9.The voltage-controlled oscillator of claim 8 wherein the variable current source comprises:
- a first current-bias transistor having a gate and a drain connected together at a first bias node, and a source connected to a power supply;
 - a first input transistor having a drain connected to the first bias node, and a gate receiving the input with the input voltage that varies; and
 - a first current-source transistor, having a gate receiving the first bias node, for varying current delivered to the source node in response to the first bias node.
- [c10] 10.The voltage-controlled oscillator of claim 9 wherein the variable current source further comprises:
- a second current-bias transistor having a gate connected to a second bias node, a drain connected to an intermediate node, and a source connected to the power supply;
 - a third current-bias transistor having a gate receiving the first bias node and a drain connected to the second bias node, and a source connected to the intermediate node;
 - a second input transistor having a drain connected to the second bias node, and a gate receiving the input with the input voltage that varies; and
 - a second current-source transistor, having a gate receiving the second bias node, for varying current delivered

to the source node in response to the second bias node.

- [c11] 11.The voltage-controlled oscillator of claim 10 wherein the first and second current-source transistors have channels in series between the power supply and the source node.
- [c12] 12.The voltage-controlled oscillator of claim 11 wherein the first, second, and third current-bias transistors and the first and second current-source transistors are p-channel transistors; wherein the first and second input transistors are n-channel transistors.
- [c13] 13.The voltage-controlled oscillator of claim 8 wherein the input is generated by a loop filter capacitor that is charged and discharged by a charge pump in response to a phase comparator in a phase-locked loops (PLL).
- [c14] 14.A linearized voltage-controlled oscillator (VCO) comprising:
 - a VCO input having a varying voltage;
 - ring oscillator means, having an odd number of inverting stages arranged in a loop, for generating an output clock derived from an output of one of the inverting stages, the output clock having an output frequency that varies with the VCO input in a substantially linear manner;

internal power means for powering the ring oscillator means, the internal power means not directly connected to a power supply; wherein the inverting stages have pull-up transistors with power-supply connections to the internal power means and pull-down transistors with connections to a ground; bypass capacitor means, coupled between the internal power means and the ground, for suppressing rapid voltage changes to the internal power means; variable current source means for driving a varying current to the internal power means, the variable current source means varying the varying current in response to the varying voltage on the VCO input; and linearizing circuit means, coupled between the internal power means and the ground, for improving linearity of output frequency as a function of the VCO input, the linearizing circuit means having a series resistor and a series transistor having a channel in series with the series resistor between the internal power means and the ground; wherein the series transistor has a gate that receives a fixed voltage that does not vary with the VCO input; whereby the variable current source means supplies current in parallel to the pull-up transistors in the ring oscillator means and to the linearizing circuit means.

- [c15] 15.The linearized voltage-controlled oscillator of claim 14 wherein the linearizing circuit means has a lower effective resistance at lower voltages of the internal power means than at higher voltages of the internal power means.
- [c16] 16.The linearized voltage-controlled oscillator of claim 15 wherein the ring oscillator means has a higher effective resistance at lower voltages of the internal power means than at higher voltages of the internal power means;
wherein the linearizing circuit means compensates for the ring oscillator means.
- [c17] 17.A high-bandwidth voltage-controlled oscillator (VCO) comprising:
a VCO input;
a variable current source driving a variable current onto an internal supply node, the variable current varying in response to the VCO input;
a ring oscillator having a plurality of inverters in a loop, each inverter having a p-channel transistor and an n-channel transistor with gates connected together and to an output of a preceding inverter in the loop, and having drains connected together and driving gates of a following inverter in the loop, the p-channel transistor having

a source connected to the internal supply node and the n-channel transistor having a source connected to a ground;

a bypass capacitor coupled between the internal supply node and the ground; and

a compensating circuit connected between the internal supply node and the ground, the compensating circuit having a resistor and a compensating transistor in series, the compensating transistor having a gate receiving a fixed voltage that does not vary with the VCO input, and a channel in series with the resistor, wherein the compensating circuit has an equivalent compensating resistance that is not constant but increases with an increasing voltage on the internal supply node.

- [c18] 18. The high-bandwidth voltage-controlled oscillator of claim 17 wherein the ring oscillator has an equivalent oscillator resistance that is not constant but decreases with an increasing voltage on the internal supply node; wherein the compensating circuit compensates for changes in the equivalent oscillator resistance of the ring oscillator to produce a more linear frequency to VCO voltage curve than for the ring oscillator without the compensating circuit.

- [c19] 19. The high-bandwidth voltage-controlled oscillator of claim 18 wherein the compensating transistor is an n-channel transistor with a source connected to the ground and a drain connected to a first terminal of the resistor; wherein the resistor has a second terminal connected to the internal supply node.
- [c20] 20. The high-bandwidth voltage-controlled oscillator of claim 19 wherein the variable current source comprises:
a first p-channel source transistor having a gate connected to a first bias node, a source connected to a power supply, and a drain connected to a first intermediate node;
a second p-channel source transistor having a gate connected to a second bias node, a source connected to the first intermediate node, and a drain connected to the internal supply node;
a first p-channel bias transistor having a gate connected to the second bias node, a drain connected to the second bias node, and a source connected to the power supply;
a first n-channel input transistor having a gate connected to the VCO input, a drain connected to the second bias node, and a source connected to the ground or through a first source resistor to the ground;
a second n-channel input transistor having a gate connected to the VCO input, a drain connected to the first

bias node, and a source connected to the ground or through a second source resistor to the ground; a second p-channel bias transistor having a gate connected to the first bias node, a drain connected to a second intermediate node, and a source connected to the power supply; a third p-channel bias transistor having a gate connected to the second bias node, a drain connected to the first bias node, and a source connected to the second intermediate node.